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Silica Scale Inhibition: Effect of Organic Additives on Polymerization

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Introduction

The problem of silica scale formation is common in geothermal power production facilities worldwide. Factors such as variable fluid compositions, different plant operating conditions, and the complex nature of silica polymerization reactions contribute to make scale inhibition a difficult problem. Scale forms by molecular and particle (colloid) deposition. Colloids are produced by polymerization of aqueous silica.

One approach to controlling silica scale is to use water-soluble organic polymers that inhibit or delay the onset of polymerization. Laboratory batch experiments are being performed to test the ability of commercially available antiscalants to extend the length of the induction period during silica polymerization. The induction period should be long enough to allow the brine to pass through the surface and reinjection facilities before colloid deposition occurs. Potential antiscalants will then be tested under field conditions at a geothermal power plant.

Polymerization of Monomeric Silica

The rate of silica polymerization depends on a number of reaction conditions such as temperature, pH, ionic strength and degree of supersaturation. Under certain conditions, polymerization first proceeds through an induction period during which the rate of loss of monomer is very slow. This is followed by a period of rapid polymerization, eventually leading to the equilibrium solubility of amorphous silica. Some water-soluble organic polymers are designed to inhibit the process of homogeneous nucleation.

Experimental Conditions

Solution chemistry was based on low-pressure brines from the Dixie Valley Geothermal Field, Nevada, which precipitate silica scale in surface facilities. Stock silica solutions were prepared

from sodium metasilicate and deionized water. The polymerization experiments were performed in 250 mL polyethylene bottles maintained at 90°C in a circulating water bath. Initial concentrations of silica ranged from 615 to 620 ppm (amorphous silica saturation index = 1.6). Control experiments were initiated by adjusting the heated solutions to a pH of 7.5 using hydrochloric acid. Inhibitor runs were performed by adding the water-soluble polymeric inhibitors prior to pH adjustment. Monomeric silica concentrations were determined spectrophotometrically using the silicomolybdate method.

Description of Experiments

Experimental Series	Description	No. of Runs
Control Experiments	No Inhibitor	16
Inhibitor #1	Good-Rite K-XP212, 100 ppm	3
	Good-Rite K-XP212, 30 ppm	4 *
	Good-Rite K-XP212, 10 ppm	3
	Good-Rite K-XP212, 3 ppm	3
	Good-Rite K-XP212, 1 ppm	3
Inhibitor #2	PermaTreat 510, 100 ppm	4

* = the inhibitor was added after 290 minutes in one of the four experiments

Good-Rite figure caption

The B.F. Goodrich Good-Rite K-XP212 copolymer showed observable inhibitory activity at a concentration of 1 ppm but its performance was improved significantly at a dosage of 10 ppm. A less pronounced effect was observed when this inhibitor was added after the onset of polymerization.

PermaTreat 510 Figure caption

The PerLorica PermaTreat 510 polymer was evaluated at a dosage of 100 ppm. A modest lengthening in the induction period, compared to the control runs, was observed at this concentration. Whereas the Good-Rite product is designed for both inhibiting silica polymerization and dispersing colloids, the PermaTreat product apparently only acts as a dispersant which inhibits the agglomeration and deposition of colloidal silica.

Good-Rite Histogram caption

The control runs had induction periods averaging 160 minutes. The induction period was extended to 230 minutes at a Good-Rite K-XP212 dosage of 1 ppm, and to 350 minutes at an inhibitor level of 3 ppm. Induction periods longer than 380 minutes were observed with inhibitor dosages of 10 ppm or greater.

Results and Summary

- Silica polymerization kinetics were measured in low ionic strength solutions at 90°C, with initial silica concentrations ranging from 615 to 620 ppm.

- Polymerization of silica was studied by monitoring the disappearance of monomeric silica spectrophotometrically using the silicomolybdate method.

- Two water soluble organic polymers, Good-Rite K-XP212 and PermaTreat 510, were evaluated for antiscalant activity by monitoring their effects on the length of the induction period as a function of dosage.

- Under these experimental conditions, the Good-Rite copolymer was effective at lengthening the induction period at low dosage levels. It was less effective when added after the onset of polymerization.

- Design of an effective scale inhibition system should include determination of the extent of polymerization at sample points throughout the surface facilities. The selection of the appropriate inhibitor and the site of its addition will depend on the polymerization state of silica.

- These preliminary results are being used to screen high molecular weight polymers for potential antiscalant activity. Their activities in flow-through experiments will be evaluated next, followed by on-site studies using actual geothermal fluids under operating conditions.

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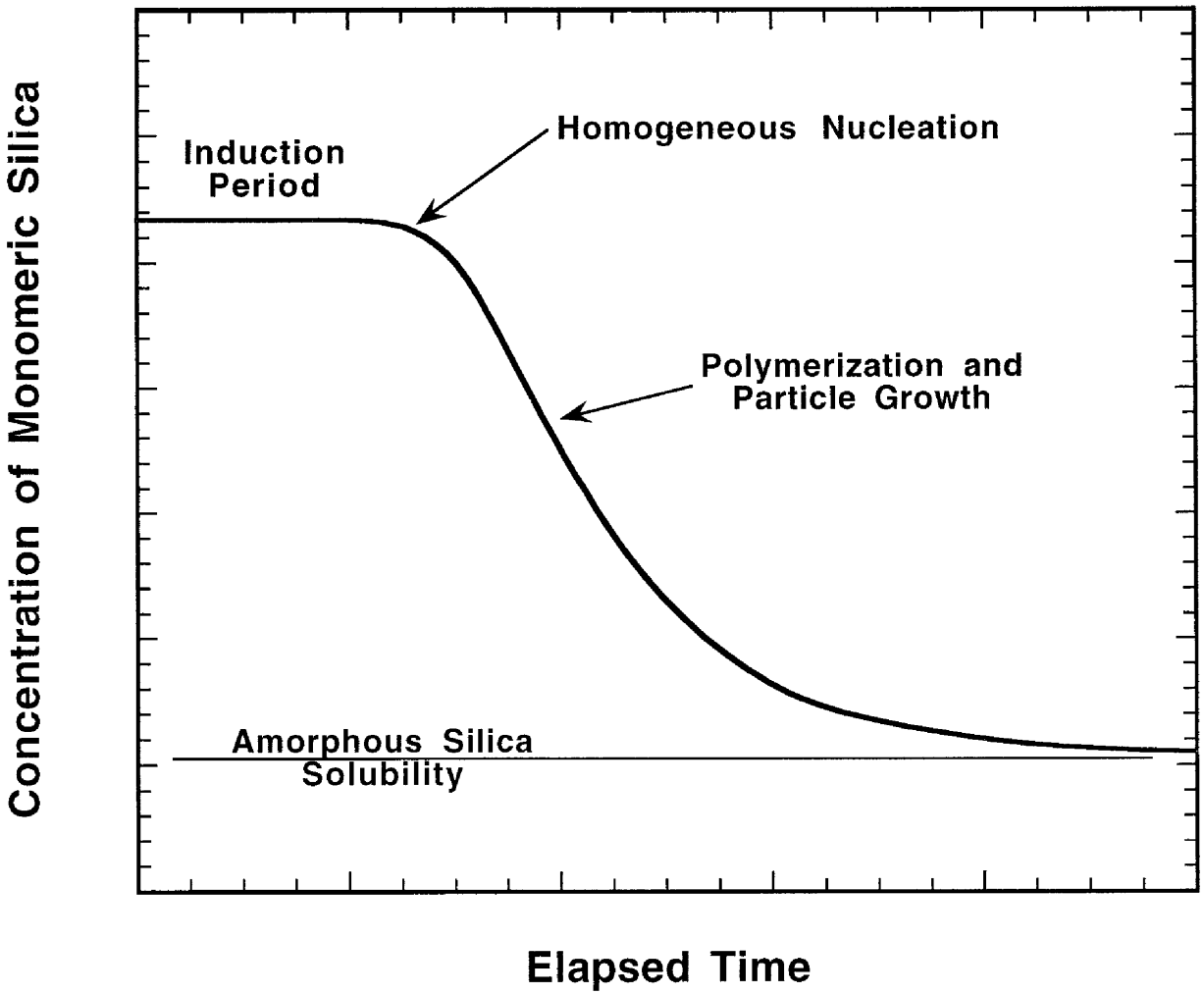
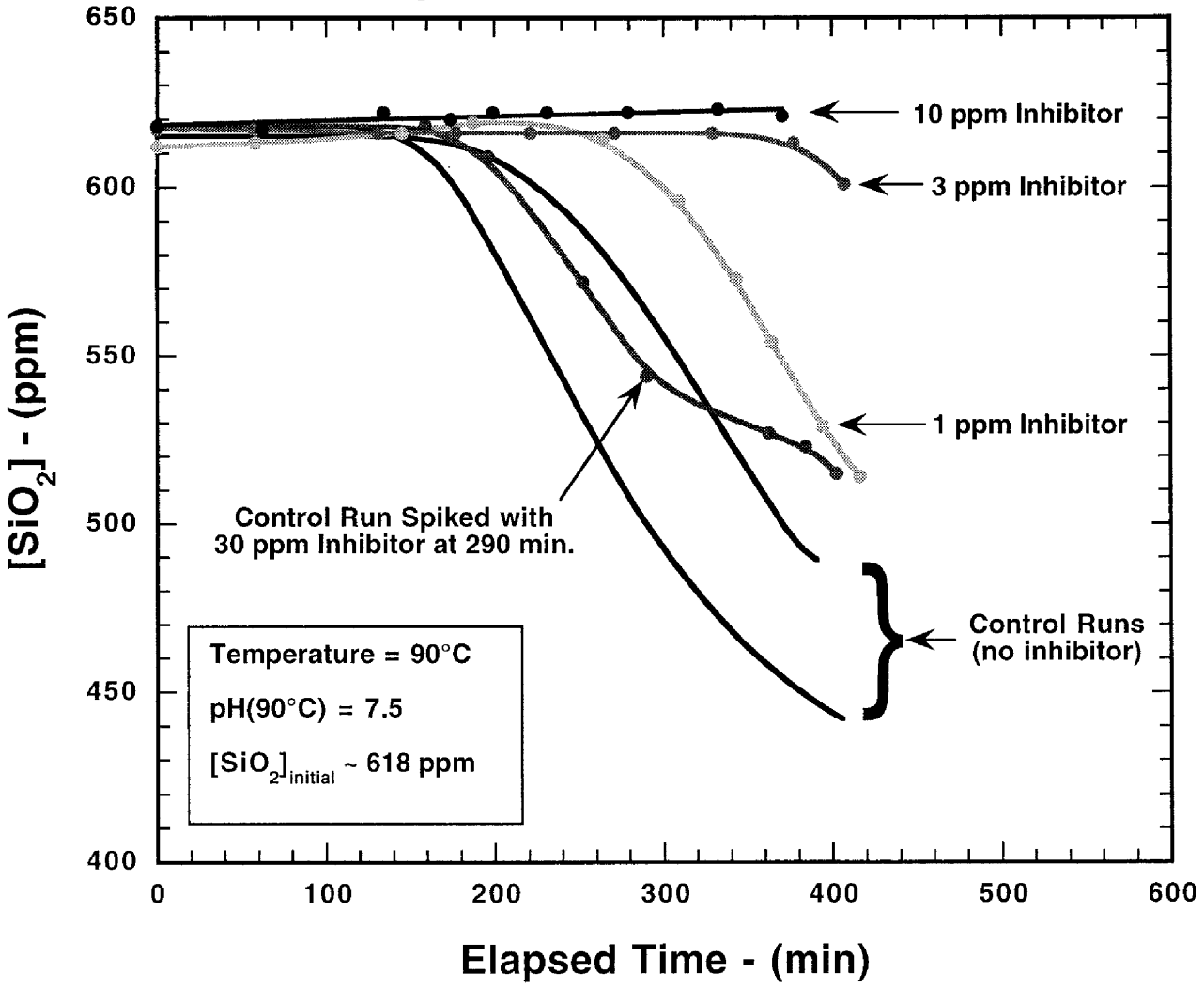
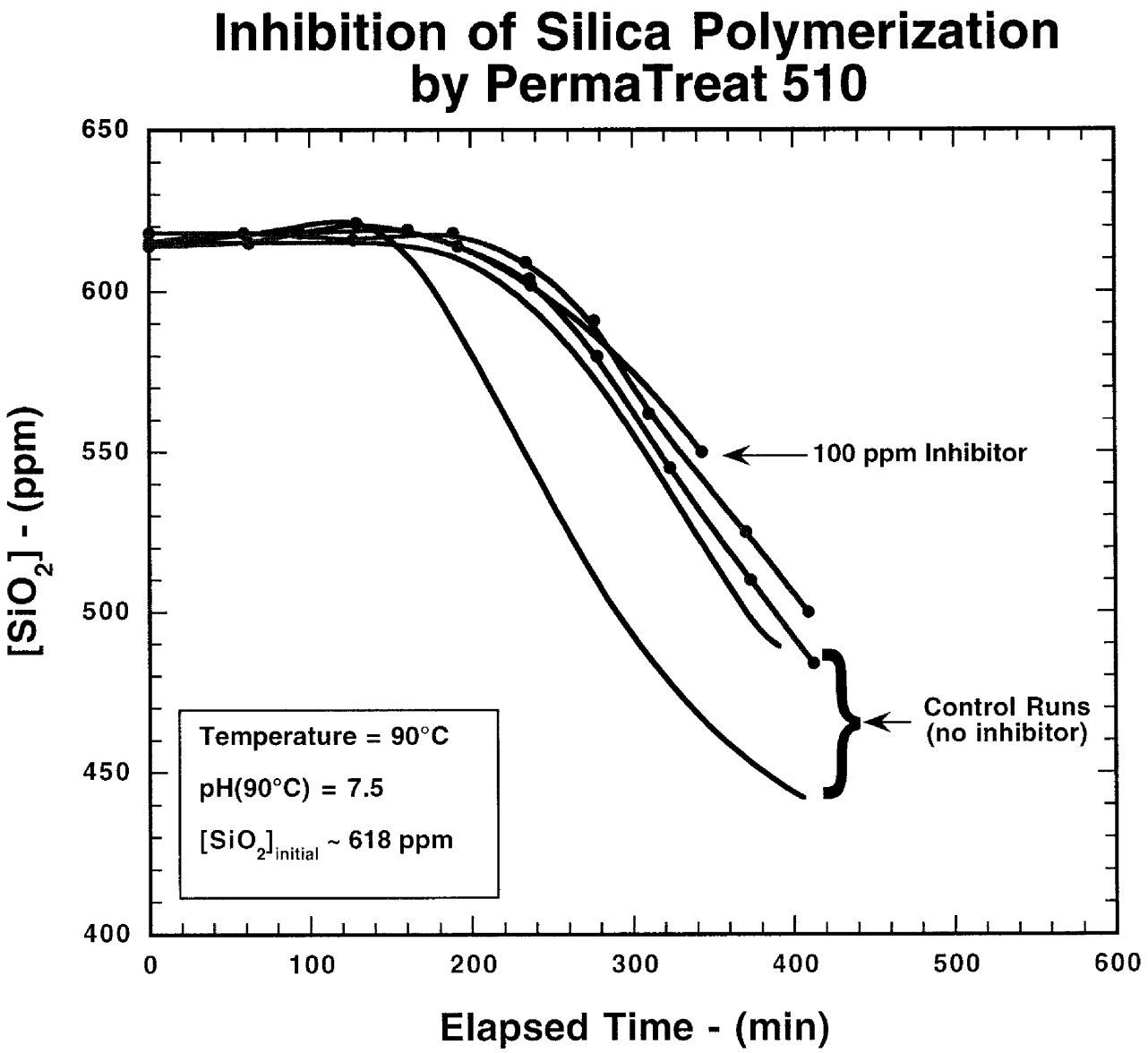
Polymerization of Monomeric Silica



Inhibition of Silica Polymerization by Good-Rite K-XP212




Inhibition of Silica Polymerization
by PermaTreat 510
650
600
550
500
450
400
0
100
200
300
400
500
600
[SiO2] - (ppm)
Elapsed Time - (min)
100 ppm Inhibitor
Control Runs
(no inhibitor)
Temperature = 90°C
pH(90°C) = 7.5
[SiO2]initial ~ 618 ppm

Effect of Inhibitor Dosage on Induction Period